Workshop Without Walls: Upstairs Downstairs

Breakout Group 1 Note-taking

There's no silver bullet. What will tell us if a planet is habitable? Inhabited?

Presence of life :)
Carbon-based.
How do we define life?
If you see E.T. waiving back, that's easy.
Working definition: understand how a planet operates w/o life. If you see sth different, then there is life.
Usually expressed in terms of disequilibrium in atm
After today's discussion: do we want to use "plate tectonics" or "crustal recycling" or "interior-atm exchange"?
Life-volcanism connection: need a stable climate? Liquid water? What is that link b/w recycling/climate stability and life?
Energy. Redox gradients, chemical energy and nutrient gradients. Expressed in Earth's oceans at mid-ocean ridges, also at geysers. Interfaces b/w interior and surface. Communication.
Clearly that concept doesn't require plate tectonics as defined by Adrian. But communication is key.
Vertical cycling as Adrian described could work too.
It's not just the exchange. Also its byproducts, such as rates of weathering & outgassing.
Sequestration due to precipitation + outgassing. Crucial to make climate stable enough for life to survive and thrive. Climate stability might mean different things at different times.
Does stability matter uniformly across a planet's surface in the same way?
On stagnant-lid planets: intuition for volcanic outgassing, but not for weathering.
Most of heat loss on Earth is at ridges, but you might not have those.
On Io, mountains are built b/c lithosphere is compressed. You have an atmosphere. If you could maintain it for a while that would work.
Mars: There was never a hydrological cycle in the sense of long-distance transport of weathering products to an ocean. Or was there?
Formation of a chemical reactor whereby you can form carbonates, so as to sequester CO_2.
Does having an ocean/large bodies of standing matter/flood plains matter for a carbonate-silicate cycle? How would the feedbacks be affected w/o them.
Impact energy can help form amino acids. But that's so far from life, as we know it!
We aren't really talking about plate tectonics, but about volatile cycling. How much are volatiles recycled on Venus? What volatiles exist on Venus? CO_2.
Could you have plate tectonics w/o life? Or is life necessary for plate tectonics? What kinds of geophysics are made possible by life? Any such process would be a huge discovery.
Life changes the composition of sediments subducted in arcs. There's a paper: Dennis Honing?

Putting back plate tectonics at 3.5 Ga is optimistic. Actually, 4.4 Ga is. Why “optimistic”? By that point, presumably, life already existed. At 2.9 Ga there was a biosphere. Which came first? Greenstone belts, etc. look like made by tectonics. But Pilbara, S. Africa komatiites: there was diversity on early Earth.
Late estimate of plate tectonics onset: 650 Ma.
When did widespread subduction start? Consensus on Archean. Evidence from diamonds with subducted surface material-like inclusions.
But others say there was evidence of plate tectonics at >4 Ga. Certainly not a solved problem. Maybe parts of the planet had plate tectonics and other parts didn’t.
What happens when subduction strats? Changes in outgassing and weathering rates. Anything else? Composition of erupted material, could be key. Environmental diversity. If you play at the origin of life lottery, you want as many tickets as possible. With many different temperatures, chemistry, odds for primordial soup to yield life are better.
Can you imagine a dataset that would be conclusive evidence of plate tectonics? Would that be a spectrum, or other planetary properties? Put a seismometer on it :)
Earth from space: narrow zones of deformation. Mountain belts. Volcanic chains. What about planet oblateness? Meh.
Having 30% felsic material above sea level implies something about Earth’s tectonic regime. Continents are defined by a buoyant, felsic rock compared to mafic ocean rock found in ocean basins. Plate tectonics, with subduction of water-bearing material, helps make continents. So observing both felsic and mafic material could be compelling evidence of plate tectonics.
30% landmasses could be all ocean islands. How do we tell they’re felsic?
Sea level doesn’t matter so much, but felsic composition does. If we see felsic material, we might more likely assume the whole interior is felsic. C/O and Mg/Si might vary a lot from system to system. So recycling or plate tectonics might have very different surface expressions in such systems. Basically, we need the stellar composition too.
What we’re going to measure first are atm gases, and we’ll understand them better than anything else. Any atmospheric evidence of volatile cycling? Also need stellar type, spectral energy distribution, understanding of the surface sinks for any given species. In the absence of that, you are limited to the disequilibrium argument.
Relatively high O2 and CH4 (100 ppm CH4 and 0.1 bar O2) would be very interesting. Suggest you have large fluxes of both.
Can you get O2 fluxes from a planetary interior? What would the background look like if there is no life? What abiotic processes pump oxygen? What are the rates of recycling? What are the atmospheric tracers of such processes? 3He?

If you could measure anything in an exoplanet, what would it be?

Planet with no sign of volatile cycling => no plate tectonics. You can rule it out. But you can’t rule out habitability?
Surface temperature: can it be measured? It can be deduced from building P-T atmospheric profiles and measuring T at top of atmosphere.

Atm proxy of volatile cycling? How do we tell what depths a magma is coming from? On Earth, depth of magmatism isn't related to plate tectonics. Or volatile cycling.
Stagnant lid: antithesis of recycling of surface materials. How do you get recycling of surface materials into the deep interior under these conditions? Negatively buoyant drips wouldn't work with surface material. Piling up of material. So maybe in this sense subduction is necessary.
The Earth has a tiny amount of water on the surface. How did we get so lucky as to not be completely ocean-covered? Can any feedbacks regulate this? Poorly understood.
Lots of water needed for core formation? But where would that water go?